Community Assistantship Program

RREAL Solar Thermal Heating Assistance

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SUBJECT: RREAL SOLAR THERMAL HEAT CBA PROJECT
SUMMARY OF OPTIONS FOR PREDICTING FUTURE ENERGY PRICES

There are several viable options available for making the 30 year estimates of prices for each type of energy (natural gas, electric, distillate fuel oil, and LPG/propane) used by Minnesota households for heating. The comprehensive predictions contained in the Annual Energy Outlook 2007 are the leading source for predictions regarding energy use, production, imports, and, most importantly, prices. Other than the AEO, the only comprehensive model of US energy markets is produced by Global Insights, Incorporated, a private consulting firm. In recent years, the results in the models produced by GII and AEO have been generally similar.

The choices for how to build the estimates of energy prices for 30 years into the future include the "cases" offered in the AEO as well as projections based on historical data analyzed in the earlier task in this project. (The results of which have been entered into the Excel worksheet entitled Energy.prices.xls.) The data obtained from the analysis in the earlier part of this project showed the mean percentage change in the nominal price of each source of fuel over both the 15- and 30- year time frames. The analysis also included the mean percentage change in the real (2007 dollars) price of each source of fuel over both the 15- and 30- year time frames. The following table summarizes the mean changes in the price of each fuel source:

Fuel Type	**77-06 Nominal**	**77-06 Real**	**91-06 Nominal**	**91-06 Real**
Natural Gas	6.99%	2.55%	6.66%	3.78%
Electricity	3.37%	-0.89%	1.82%	-0.91%
Distillate Fuel Oil	7.23%	2.76%	6.44%	3.56%
LPG/Propane	n/a	n/a	6.08%	3.48%

The following are some of the methods for estimating the fuel costs over the next 30 years:

Option 1: AEO 2007 reference case.

Option 2: AEO 2007 economic growth cases (high economic growth or low economic growth).

Option 3: AEO 2007 price cases (high petroleum prices or low petroleum prices).

Option 4: Historical price growth rates using nominal price changes (from the 1977-2006 period or the 1991-2006 period).

Option 5: Historical price growth rates using real price changes (from the 1977-2006 period or the 1991-2006 period).

With any of the above options, we will also need to include estimates of the rate of inflation over the entire 30 years of the analysis. Under each of the first three options, the projected rate of inflation would be used to convert the real energy prices in the AOE into nominal prices in each of the 30 years in the analysis. The projected rate of inflation will be used similarly under option 5, after the estimates of real energy prices have been derived by applying the historical growth rates. The projected rate of inflation would be used differently under option 4. This option first applies the historical nominal growth rates to obtain nominal energy prices in the 30 years of the analysis. Then, the inflation rate would be used to derive the real prices from the nominal prices.

While the AEO contains projected rates of inflation for each of the cases in the AEO 2007, there are other forecasts of inflation using the CPI-U, the CPI-W, PPI and the GDP deflator. Most such forecasts from private sources (economic consulting firms) extend only a year or two into the future. Those few sources of long-range projections of inflation rates which are available may be found in publications of certain federal government agencies. In addition to the AEO 2007 report's estimate of long run inflation, federal government agencies with recently-issued reports incorporating assumptions for long-term inflation include the Federal Aviation Administration (FAA) and the Social Security Administration (SSA). The SSA's advanced actuarial reports support the OASDI Trustees Report, which contains three assumptions each with a different level of price inflation over the long term. The FAA's Aerospace Forecasts for Fiscal Years 2007 – 2020 incorporate the most recent long-range inflation prediction from the Office of Management and Budget, while the USDA report on US and world agriculture markets uses an assumption of 2.5% annual inflation.

Source	**Reference or Intermediate**	**High Inflation**	**Low Inflation**	**Index Estimated and Duration**
AEO 2007	2.0%	2.5%	1.5%	CPI-U through 2030
OASDI Trustees 2005	2.8%	3.8%	1.8%	CPI-W through 2080
Aerospace Forecasts FY 2007-2020	2.3%	n/a	n/a	CPI through 2020
USDA 2007	2.5%	n/a	n/a	CPI through 2016

RREAL SOLAR THERMAL HEAT CBA PROJECT
PREDICTING FUTURE ENERGY PRICES

The Energy Information Administration (EIA) of the United States Department of Energy publishes projections for energy prices which extend 30 years ahead. Each year's projections include the most likely estimate (the "reference case") as well as a variety of alternative case scenarios. In recent AEOs, the alternative case scenarios have been based upon different assumptions regarding petroleum prices, alternative levels of economic growth, and a variety of other variables related to energy efficiency, specific energy efficiency technologies, and environmental or energy policy. The projections are published in the Annual Energy Outlook (AEO), the most recent version of which is the basis for much of the information which will be described here (Energy Information Administration. 2007a).

National Energy Modeling System

The projections in the AEO are based on results from a sophisticated set of economic models known as the National Energy Modeling System (NEMS). The following paragraphs summarize the architecture, operation, and key characteristics of the NEMS. In evaluating an economic model, the model's assumptions are often of particular importance. This is certainly true in this evaluation of the NEMS. Thus, much of this section will present a summary of the NEMS using the available detail from the "Assumptions to the Annual Energy Outlook 2007" report (Energy Information Administration. 2007c)and the appendix to the most recent AEO report (Energy Information Administration. 2007d)

The NEMS is comprised of a number of modules each representing the supply and demand conditions in one particular fuel supply market, conversion sector, or consumption sector. Each module functions at the level of a relevant region in order to represent the geographic differences in each of the markets for consumption, supply and conversion. For the consumption sectors, regions are based on the census districts which divide the country into nine regions. For the supply markets and conversion sectors, various geographic regions specific to the particular market are used. The NEMS also includes a module which predicts petroleum supply from the international sector. The supply estimates produced by the international module include supplies of each of the five different forms of crude oil and 17 various refined petroleum products. Supply from each of the more than 200 countries/territories in the world is estimated by the international module.

Each NEMS case begins with a series of assumed macroeconomic conditions. Economic growth is an important driver of energy demand and the NEMS was built to reflect this relationship. The NEMS includes a macroeconomic activity module in which energy demand is influenced by projected gross domestic product, disposable income, industrial output, new housing starts, light-duty vehicle sales, interest rates, prices (inflation), and employment. The underlying macroeconomic estimates used in the NEMS are based on three models of the US economy produced by Global Insight, Incorporated. The results of these macroeconomic models of the entire US economy have been adapted to the nine census districts used by NEMS as energy consumption regions.

Gross Domestic Product is the broadest measure of economic activity and the most important macroeconomic assumption in the NEMS. It is possible to obtain an oversimplified estimate of how assumptions regarding GDP relate to projections for the prices of natural gas and petroleum products in the NEMS. Comparing the projections in the two case scenarios regarding economic growth – high economic growth and low economic growth – provides an approximate measure of how forecast errors in economic growth affect forecasted fuel prices. In the 2007 AEO, the reference case is based on long-term economic growth in real GDP of 2.9 percent, the high economic growth case on growth in real GDP of 3.4 percent, and the low economic growth case on growth in real GDP of 2.2 percent.

The impact of differences in economic growth assumptions on energy price projections is modest. Year 2010 real natural gas (wellhead) prices are only about 3.8 percent lower under the low economic growth case and 3.5 percent higher under the high economic growth case versus the reference case scenario. Even at 2030, real natural gas prices are only 5.7 percent lower under the low economic growth case and 5.5 percent higher under the high economic growth case. The impact of economic growth projections on electricity prices at 2030 even smaller, with prices only 3.7 percent lower and higher under the respective economic growth cases. In the 2007 AEO, there is no difference (0 percent) in 2030 petroleum prices between the low and high economic growth cases. As mentioned, the petroleum price assumption is separate from the other assumptions.

The second major series of assumptions in each case included in the NEMS are for world oil prices. Assumed world oil prices represent an important input into the entire NEMS. Many sources of fuel are derived from petroleum and many non-petroleum sources of fuel have petroleum substitutes. Petroleum is a primary source of energy in the transportation sector (gasoline and jet fuel), residential sector (fuel oil and LPG), commercial sector (fuel oil), and industrial sector (LPG and petrochemical feedstocks). Because of the substitutability of petroleum products for competing sources of energy in each sector, petroleum prices affect the demand for nearly all other sources of fuel. Rising petroleum prices increase the demand (and thus prices) of non-petroleum sources of fuel, while declining petroleum prices decrease the demand for non-petroleum fuels.

Even without access to the details of the modules comprising the NEMS, it is possible to obtain a broad estimate of the impact of the substitutability of petroleum for other fuel products. By economic logic, a positive cross price relationship between a pair of commodities indicates substitutability between the two. Using the three petroleum price cases in the AEO 2007 to estimate the impact on natural gas prices of changes in oil prices shows a range generally between 0.25 and 0.5. This means that the NEMS model suggests that a higher petroleum price translates into a proportional price percentage increase in natural gas prices. For example, for a petroleum price which is 25 percent greater than the reference case, the predicted natural gas price would be 6.3 to 12.5 percent greater than the reference case. (Notice that this is a useful but vastly simplified explanation of the relationship between petroleum and natural gas prices in the NEMS.)

The estimates of the real prices of petroleum are dramatically different between the price case scenarios. The real price of crude oil declines to $35.68 (2005 dollars) by 2030 under the low price case. Under the high price case, crude oil rises to $100.04 by 2030. (The real price of crude oil is about $59 by the year 2030 under the reference case.) Over the full duration of the 25 years estimated, the ultimate rise in real natural gas prices in the AEO2007 is minimal under the high price scenario, however. Under both the low price and reference case scenarios, the real price of natural gas falls significantly over the 25 years estimated. The real price of electricity is only minimally lower under the low price case, and minimally higher in the high price case.

Sources of Prediction Error in he NEMS

The patterns of errors observed in the NEMS and an overview of how the system predicts energy prices reveals a number of limitations in its ability to make accurate predictions. The pattern of errors seen in predictions for the prices of petroleum, natural gas, and coal reflect a reasonable amount of misspecification and errors in the detailed component modules for each of the conversion, consumption and production sectors. These errors are explicitly acknowledged in the AEO Retrospective reports published each year. (See the following section regarding the sources of error acknowledged in the AEO.) The largest overall source of error in the NEMS, however, results from inaccurate estimates of petroleum prices.

A series of world petroleum prices are assumed at the beginning of each case estimated in the AEO. The real world price of petroleum is estimated for each of the 30 years in the forecast. The NEMS then uses the forecasted petroleum prices as *assumptions* under each of the estimated cases. The reasonableness of assumed world petroleum prices is thus of paramount importance to the projections in the AEO. If petroleum price assumptions are unreasonable, the entire range of energy prices predicted will be ineffectual. In recognition of the paramount importance of assumptions for world oil prices, the AEO now contains two alternative cases: the high petroleum price case and the low petroleum price case. The supplemental documentation on the NEMS International Module states that assumptions regarding OPEC and non-OPEC supplier behavior provide the key assumed difference between the high- and low- petroleum price cases and the reference case (Energy Information Administration. 2007d). The inclusion of the three widely divergent pertroleum price scenarios seems to have resulted from the large amount by which oil prices have been inaccurately forecast under the NEMS in recent years.

Self-Reported Accuracy of Energy Price Forecasts under NEMS

Each year, the EIA produces a report summarizing the accuracy of the energy price predictions in prior years' AEOs in a report entitled "Annual Energy Outlook Retrospective Review" (Energy Information Administration. 2007b). The report compares the projected prices and quantities to the actual prices and quantities for each of the more than one dozen energy products used in the United States. The projected prices and quantities for each product in each year are compared to actuals and percentage deviations and direction (over- or under- estimated) are reported. Each year's Retrospective also gives a short narrative description of the main sources of error seen in AEO estimates. The findings of the most recent Retrospective Report are analyzed in the following few paragraphs.

Information on forecast errors in recent Retrospectives clearly shows the NEMS has been far more accurate in predicting quantities of energy products than prices. Since the implementation of NEMS with the 1994 AEO, estimates of quantities consumed, produced, and imported have generally been within five percent of actual quantities. However, estimates of the prices of energy products have often been far from the actual prices. The mean absolute percentage difference between the forecasted price of crude oil and the actual price has been almost 21 percent. The largest forecast error has been in estimates of natural gas, with the mean absolute deviation being 29 percent. The mean absolute deviation in electricity prices has been smaller, but still approaches 10 percent. The direction of these forecast errors in energy prices has varied, with underestimates for petroleum and natural gas prices and overestimates for electricity prices being common.

NEMS Reported Forecast Errors for Petroleum

The world oil price is the single most important exogenous (assumed) variable in the entire NEMS. The most recent Retrospective review acknowledges world oil prices have been consistently underestimated beginning with the 1997 AEO. The significant forecast error in the world oil price causes substantial errors in the prices of a wide variety of petroleum products. The underestimation of world oil prices also results in underestimates for many other non-petroleum sources of fuels, given the substitutability modeled in the NEMS. The accuracy of forecasts of future world oil prices is critically important to the overall usefulness of the EIA projections. The failure of EIA forecasts to anticipate high oil prices over the last decade has resulted in very poor estimates of final petroleum product prices. The estimates of 2005 world oil prices (each AEO since 1991 predicts energy prices to 2005 or beyond) have been misforecasts of an average of nearly 35 percent. In recent years, petroleum prices have been underestimated twice as often as overestimated.

NEMS Reported Forecast Errors for Natural Gas

The forecast errors in the prices of natural gas have been even greater than those for petroleum products. A large part of the underestimates of natural gas prices in recent years follows directly from major underestimates of petroleum prices in the reference cases. However, the Retrospective hints at other factors in the natural gas production and conversion sectors which were not accurately accounted for in the NEMS. The factor with the largest suggested impact on the massive under forecasts of recent years is the increasing demand for natural gas in the electricity-producing sector following the deregulation of the industry. Beyond the missed impact of the greater substitution of natural gas for other forms of fuel in electricity production, though, the Retrospective appears to offer little explanation for why the AEO has underestimated natural gas prices so much in recent forecasts. The 2005 natural gas price has been underestimated by an average of nearly 50 percent, with every one of the AEOs between 1991 and 2005 containing a significant underestimate.

NEMS Reported Forecast Errors for Electricity

Forecast errors in the prices of electricity have been smaller than those for petroleum and natural gas, and have usually been overestimates rather than underestimates. The electricity generation sector has the ability to substitute different fuels, so estimated prices for both coal and natural gas contribute to the estimates for electricity prices. Over the history of NEMS' energy price projections, overestimates of electricity costs are more common than underestimates. Earlier AEOs (ie 1991 to 1996) tended to overestimate prices of coal, but more recent projections have underestimated the prices of both coal and natural gas. As a result, the AEOS since 1997 show consistent underestimates of electricity prices. While the forecasts from AEOs in the early 1990s contain overestimates of 2005 electricity prices by as much as 50 percent, AEOs since 2000 have generally underestimated 2005 electricity prices by an average of 12 percent.

Unacknowledged Sources of Inaccuracy in the NEMS

The NEMS, as described above, is a sophisticated system of interconnected modules under which long-term energy prices are determined by simulated supply and demand conditions. Each of a number of the individual producing, conversion and consumption markets are modeled. As such, the NEMS could be described as an essentially microeconomic-based system of models of separate but connected markets. Under this system, the macroeconomic variables and world oil prices are taken as assumptions with only limited feedback from the energy models to the macroeconomic model. Making assumptions about world oil prices and macroeconomic conditions introduces a potentially large amount of error into price estimates under the NEMS. The following section briefly offers some sources of error apparent in the NEMS assumptions.

Inaccuracy in Assumptions of World Petroleum Prices

The market for petroleum crude oil is global and prices in commodity markets around the world are equivalent except for small but consistent differentials based on grades of sulfur-content between oil from different production regions. The factors which influence world oil prices are truly global in that supply and demand from all countries combine in determining the price of petroleum. Although the NEMS does also predict quantities of crude oil imported from each country into the US, it lacks a fully integrated model of supply and demand in the international market for oil. **Simply put, the NEMS has no overall model of the global crude oil market.** As a result, the world petroleum price assumptions used in the NEMS are essentially based on an incomplete model of world petroleum supply and demand.

The lack of a complete model for the international supply and demand for world oil suggests that many of the major factors in higher world oil prices in recent years are being missed. Much of the recent increase in petroleum prices has resulted from increases in demand from rapidly expanding economies in Asia and elsewhere. Strong economic growth in the large Asian economies has driven demand higher, with demand growth in China and India expected to continue to be strong (Luguang. 2007;Xinhua News Agency. 2007). In the incomplete model of world oil supply and demand under the NEMS, strong Asian demand growth is essentially unrepresented in world oil prices. The AEO assumptions include a 2.9 percent annual demand growth rate in non-OECD Asian countries (Energy Information Administration. 2007c). Aside from the problem with the incomplete model of world petroleum prices, **the projected level of less than three percent annual growth in Asian petroleum demand appears unrealistically small.** Recent growth rates in demand from the largest Asian oil importing nation, China, have averaged as much as 15 percent annually (AFX Asia. 2007;Wardell. 2007).

The assumed world oil prices are not usefully related to the value of the US dollar by the NEMS. American refiners purchase oil on the international market, where oil prices have traditionally been quoted in US dollars. The status of the US dollar as a global measure of account, however, is increasingly challenged by other currencies (particularly the Euro). The dollar price of world oil would be significantly affected by the commodity being quoted in another currency. Dollar prices would then reflect volatility in both the value of the currency and the commodity. The implications of a commodity priced in foreign currency has been the subject speculation and of academic research. The research has found that the use of a foreign currency to price oil would have resulted in higher American petroleum prices and greater price variability (Tucker. 1992). The AEO, however, provides **no information about the projected value of the currency in the assumptions used in estimating world petroleum prices.**

A less fundamental problem which nonetheless compromises the usefulness of the AEO 2007 long term energy price projections is the exclusive presentation of real prices for world prices of energy commodities. The use of real prices simplifies comparisons across time periods and is particularly useful when, as in the AEO, projections span a long period covering many years. This allows comparisons in constant dollars and eliminates the effects of price inflation. However, by providing *only* real prices, the AEO makes it difficult to distinguish the origins and assumptions behind the world petroleum price predictions. On top of the omission of foreign currency information discussed above, the interpretation of real prices in the AEO 2007 is difficult. For any predicted world petroleum price in real dollars, it is impossible to understand **how much of the real price depends on changes in the value of the US dollar and how much represents a change in the currency-neutral price of petroleum in global markets.** Without this supporting contextual background, the real prices in the AEO are difficult to assess for their reasonableness.

Inaccuracy in Assumptions of Natural Gas Prices

Inaccuracy in forecasts of petroleum prices are the primary sources of error in natural gas prices, but there are other sources of error, as well. The Retrospective report summarizes several errors in the Natural Gas modules on page 2 (Energy Information Administration. 2007b). These include underestimates of the rate of change in technological growth in the natural gas production (drilling) sector and regulatory changes in the utility industry. The regulatory changes which now allow electricity producers more flexibility to use natural gas have been incorporated into more recent AEOs. Yet the significant underestimation of natural gas prices has continued. This is more evidence suggesting that the **NEMS lacks the appropriate models to accurately predict natural gas prices.** Some factors which are missing from the NEMS which may reasonably be seen affecting natural gas prices would include the value of the US dollar and supply and demand in the Eurasian natural gas market. Neither of these factors are incorporated into any of the modules of the NEMS.

Conclusions Regarding Inaccuracies in NEMS

Given the variety and complexity of global energy markets and the lack of predictability of world geopolitical events, weather conditions and natural disasters, there are serious questions about the usefulness of any predictive model. The complex models in the NEMS (and other similarly-detailed systems, such as that offered by Global Insights, Inc) perform well in modeling policy changes, where a comparison is between two distinct formulations of the model. However, its usefulness in general predictions of a broad range of energy prices remains doubtful. The EIA now provides a few alternate cases between which users can choose in making projections. Yet even the alternate price case assumptions are based on incomplete models of world petroleum markets. The result is that **alternate case estimates in the AEO may be unrealistic and of little value to most users of energy price information.**

Inflation and Energy Prices

As the sophisticated detailed models of the NEMS have not proven to be useful in general predictions of energy prices, other approaches might be considered. One useful comparison would involve assumptions regarding the rates of growth in energy prices over long time periods. The potential simplicity of this approach (as compared with the NEMS) belies some important tendencies for energy prices to rise at faster rates than the overall price level. Over the past 15 years, prices for heating oil, natural gas, and propane have risen at more than twice the level of general inflation. The relationship between energy prices and inflation over the past 30 years has been similar. This remarkably consistent relationship is observed across three of the four main sources of residential heating fuel used by Minnesota households.   See Table 1.

Table 1: Mean Annual Changes in Prices of Residential Energy Fuel Sources

Fuel Source	**Nominal 1977-2006**	**Nominal 1991-2006**	**Real 1977-2006**	**Real 1991-2006**
Natural Gas	7.0%	6.7%	2.6%	3.8%
Electricity	3.4%	1.8%	-0.9%	-0.9%
Fuel Oil	7.2%	6.4%	2.8%	3.6%
Propane		6.1%		3.5%

Sources: “Energy.prices.xls” containing author’s calculations from various EIA sources.

While there is a clear positive relationship between energy prices and general price inflation, it is difficult establish cause and effect. The interaction between energy prices - determined largely in international commodities markets - and US domestic prices is complex and ambiguous. The predominant view would be that world energy prices act as an “independent variable”, being determined in the exogenous world commodity markets and unaffected by US domestic price inflation. This represents an modest oversimplification of the true nature of the relationship. The world prices of commodities will depend upon the value of the US dollar and the value of the US dollar is, in turn, influenced by domestic inflation. Nonetheless, any indirect feedback from domestic inflation to world energy prices is likely to be minimal.

World energy price changes constitute only one factor in overall domestic inflation. Inflation in the domestic economy is indicated by such widely-watched macroeconomic variables as labor productivity, unit labor costs, import prices, capacity utilization and others. Given the size, diversity and dynamic nature of the US economy, assuming a causal relationship between world energy prices and domestic inflation would amount to an unreasonable oversimplification. Even though energy prices are a significant factor, US domestic inflation is influenced to a greater extent by technology advances, productivity growth, government fiscal policy, monetary policy, and other important factors. So, in spite of the apparent consistency in the relationship between energy prices and overall inflation (as shown in Table 1), it would be wrong to base an estimate of overall inflation mainly on energy prices. Macroeconomic factors will continue to provide a better estimate of increases in overall price levels.

An Alternative, Inflation-Based Model of Energy Prices

Thus, a sound alternative model of domestic energy prices might be one which was based separate estimates for world energy prices and for domestic inflation.   The prediction used for overall inflation would incorporate a broad measure of price increases across all sectors of the domestic economy over the long term. This long run inflation prediction would be based upon the macroeconomic factors which affect economy-wide prices, such as government fiscal policy, monetary policy, technology growth, labor force growth, etc. This broad prediction of overall inflation would include prices in the energy sector as well as the manufacturing, service and other sectors of the economy.

The second component of the model would be a separate estimate of increases in the real prices of world energy. Used in conjunction with the estimate of overall domestic price inflation (which would include prices in the energy sector), this estimate can be stated *net* of the overall rate of price inflation (in other words, the rate of *real* price inflation). So, if energy prices are projected to rise at the overall rate of inflation, the real rate of inflation in energy prices would be 0 percent. If energy prices were expected to rise faster than overall inflation, the real rate of inflation would be positive. If energy prices were expected to rise slower than overall inflation, the real rate of inflation would be negative. The estimated real rate of energy price changes would be properly based on factors which are likely to influence the dollar cost of world energy, such as the value of the US dollar and international energy supply and demand.

Specific Estimates of Overall US Inflation

The first projection in this alternative model of energy prices would be for the overall rate of inflation. Those few sources of long-range projections of inflation rates available tend to be found in publications of certain federal government agencies. In addition to the AEO 2007 report's estimate of long run inflation, federal government agencies with recently-issued reports incorporating assumptions for long-term inflation include the Federal Aviation Administration (FAA) and the Social Security Administration (SSA). The SSA's advanced actuarial reports support the OASDI Trustees Report, which contains three assumptions with different levels of long term price inflation. The FAA's Aerospace Forecasts for Fiscal Years 2007 – 2020 incorporate the most recent long-range inflation prediction from the Office of Management and Budget. The USDA report apparently made its own assumption regarding the rate of US price inflation. These estimates of the long run rates of inflation are summarized in the following table.

Table 2: Long run Inflation Estimates by Federal Agencies

Source	**Reference or Intermediate**	**High Inflation**	**Low Inflation**	**Index Estimated and Duration**
AEO 2007	2.0%	2.5%	1.5%	CPI-U through 2030
OASDI Trustees 2005	2.8%	3.8%	1.8%	CPI-W through 2080
Aerospace Forecasts FY 2007-2020	2.3%	n/a	n/a	CPI through 2020
USDA 2007	2.5%	n/a	n/a	CPI through 2016

Sources: Annual Energy Outlook 2007, Energy Information Administration; 2005 OASDI Trustees Report, Social Security Administration; Aerospace Forecasts FY2007-2018, Federal Aviation Administration; Long Term Projections, United States Department of Agriculture.

The projections of long run rates of inflation offered in these federal government agency publications are quite similar. The most authoritative of the federal agency reports on long term fiscal conditions is usually the bi-annual Medicare (OASDI Trustees) report. Like the AEO, the Medicare report offers three scenarios, one in which inflation is higher, one lower and the intermediate one. Notice that the Medicare report projects higher rates of inflation in each of the three scenarios relative to the AEO, and the largest difference is between the high inflation scenarios. The two other federal agency reports (each of which contains only a single inflation estimate) also each project a rate of inflation above the AEO reference case. Taking the average of the AEO reference case, OASDI intermediate estimate and the FAA and USDA estimates results in a projected 2.4 percent annual long term rate of inflation. This rate will be ragarded as the best meta-estimate of long run domestic inflation available.

Estimates of Real Energy Price Increases

Among government agencies, only the Department of Energy (Energy Information Administration) provides long run estimates of increases in energy prices.

DOE energy price projections are based on NEMS reference and alternate cases and provide projections for the real prices of fuel sources through 2030 in the AEO2007. In order to use AEO2007 prices in the suggested model based on price changes, it is necessary to convert the specific price estimates in the AEO2007 to average annual percentage changes. The annual changes in prices for each of the three sources of fuel were computed from the data in the AEO2007. They are listed in Table 3, alongside the 15- and 30- year historical increases in real fuel prices.

Table 3: Growth in Real Energy Prices, AEO Predictions and Historical Averages

Fuel Source	**AEO2007 Low Price**	**AEO2007 Reference**	**AE02007 High Price**	**91-06 Average**	**77-06 Average**
NaturalGas	-1.6 %	-0.9 %	+0.1 %	+3.8 %	+2.6 %
Petroleum	-1.8 %	+0.2 %	+2.3 %	+3.6 %	+2.8 %
Electricity	-0.2 %	+0.0 %	+0.1 %	-0.9 %	-0.9 %

Source: Annual Energy Outlook 2007 and “Energy.prices.prediction.xls” containing author’s calculations using variety of EIA sources.

The factors affecting prices in world energy markets include foreign demand growth, the dynamics of foreign producer behavior, changes in the value of the US currency, domestic economic growth, energy efficiency technological advances, and alternative energy markets. Several of these factors would be extremely complicated to predict, model, or even to analyze. (Petroleum producer behavior, for example, involves an oligopolistic market structure with constantly changing dynamics both between and within OPEC and non-OPEC producers. Predicting currency values is a substantial industry in and of itself. Given the complexity in each of the world energy markets, a reasonable alternative might be to base energy prices on **observed energy prices during similar periods in recent history**.

The historical energy price data available from the EIA covers a period beginning in the late 1970s for most of the main sources of residential heating fuel. The macroeconomic, supplier, and currency conditions in the 30 years covered by the EIA may be usefully separated into two distinct eras. During the period between 1977 and the late 1980s, the US economy experienced higher overall inflation, slower average domestic economic growth, moderate foreign economic growth, a strengthening dollar, and a weakening producer oligopoly (OPEC). During the period since (beginning about 1991), the US economy has experienced lower overall inflation, faster average domestic economic growth, fast foreign economic growth, a strengthening dollar followed by a reversal and weakening, and a strengthening producer oligopoly.

Which of the two distinct eras better represents the future should guide the choice of which rate of increase in real energy prices would be preferrable. The more recent period is clearly representative of the post- Cold War reality and the current political and security situation in the Middle East. However, using the full 30 year period would allow for an "averaging" across two different eras, which might provide more accurate estimates in the event of a fundamental change in geopolitical or economic realities over the next 30 years. In order to replicate the energy price behavior under both the post-Cold War scenario and a more neutral long-run scenario, the approach in this model will offer energy projections using each of the two observed historically-based patterns of real energy prices.

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RREAL SOLAR THERMAL HEAT CBA PROJECT
ENERGY POVERTY

The Low Income Heating Assistance Program provides a subsidy which addresses the vulnerability of low income households to high energy prices. The program attempts to address the “energy poverty” of poor American families. Eligibility for LIHEAP is based on a percentage (currently 50 percent) of the median income in the state. In Minnesota, the amount of the LIHEAP award depends only partially on the measure of the actual costs of energy required by the household. The inclusion of both means, such as household income or resources, and energy acquisition requirements, such as the cost of fuel or access to energy technology, are both important components in the broader definition of “energy poverty.”

Energy poverty has been most commonly measured by the ratio between the cost of energy consumed by a household and the household’s income. Some more recent analyses have used this measure along with energy price projections, finding some of the poorest Americans facing extreme levels of fuel poverty. Powers (Power. 2005) used the fuel price projections from the 2005 Short Term Energy Outlook in her prediction that the 13 million American households in poverty would spend an average nearly 25 percent of total household income on energy. She also found that the larger group of LIHEAP eligible households (33 million) would spend an average of almost 16 percent of income on energy. The 2005 STEO eventually overestimated residential heating fuel costs somewhat, so these extreme burdens proved to be slight overestimates. Yet, the vulnerability of many low income American households to energy price fluctuations has nonetheless remained severe.

The detailed household expenditure data in the 2005 Consumer Expenditure Survey report *actual* household spending by income category. These expenditure data can be used to compute the energy expenditure-to-income ratios for households at different levels of income. The results show the dramatic differences in income devoted to energy between wealthy and poor households in the Midwest region. The data show that households in the lowest income category (those with household incomes below $10,000) spent an average of 11.4 percent of all income on fuel, while those in the highest income category spent only about 2 percent of income for residential fuel. The poorest of families thus spent more than 5 times as much of their total household income on residential energy as the wealthiest. The next poorest households (those with incomes between $10,000 and $15,000 annually) still spent about 10 percent of income on residential energy in 2005.

Income Category	Mean Fuel Expenditure	Share of Income
Less than $10,000	$890	11.4%
$10,000 to $14,999	$1262	10.0%
$15,000 to $19,999	$1327	7.6%
$20,000 to $29,999	$1540	6.2%
$30,000 to $39,999	$1665	4.8%
$40,000 to $49,999	$1754	3.9%
$50,000 to $69,999	$1897	3.2%
$70,000 or more	$2366	2.0%

Source: 2005 Consumer Expenditure Survey, US Bureau of Census

Prices for the main sources of residential fuel have risen since 2005, although the price increases were smaller than some STEO estimates had predicted. As a result, the share of households spending more than 10 and 15 percent of their total income on fuel was significantly higher during the 2006 season than would be suggested by the data in the table above. Clearly, an alarmingly large number of American households continue to suffer high levels of fuel poverty. Yet, there is no official definition of energy poverty recognized by the United States as measured by the expenditure ratio or any other definition of energy poverty.

Fuel Poverty in England

In the United Kingdom, the government's Bureau for Enterprise and Regulatory Reform (BERR) has a formal definition of fuel poverty. A household is said to be in fuel poverty if it needs to spend more than 10 percent of income to maintain a satisfactory living environment. Furthermore, the BERR goes beyond the general definition to specify that the "satisfactory living environment" includes fuel to maintain a 21 degree Celsius temperature in the main living area and 18 degree Celsius temperature in other occupied areas (Department of Trade and Industry. 2007). (Because England has a more moderate climate, few households have air conditioning and summer residential climate control expenditures are minimal.) This definition provides a basis for the British government's official goal of ending fuel poverty in the UK for households in which children, the elderly, the sick and the disabled reside by the year 2010 and in all households by 2016.

Energy Poverty in Developing Countries

While the energy expenditure to income ratio is the predominant way of measuring energy poverty in advanced economies like the US and England, economic research on energy poverty in developing countries applies very different logic in defining energy poverty. Some research uses various means of determining an "energy poverty line" which is then applied to the household's actual energy consumption. Households consuming below this energy poverty line are classified as being in energy poverty (Foster, Tre, and Wodon. 2000). Another economic approach to examining energy poverty focuses on the unit price paid for various forms of energy. Pachauri points out several studies which have shown that poorer households in developing countries often pay the highest prices per effective units of fuel consumed (Pachauri et al. 2004).

Another approach to defining energy poverty starts with estimates of energy requirements which are based on actual energy technologies. The basic energy requirements for households of a particular profile are calculated based on engineering estimates of the efficiencies of typical appliances together with specified basic needs for cooking, lighting, heating, etc. One advantage to this approach is that it allows for basic needs to be specified differently for urban and rural households, different household sizes, and different climactic regions.

A final approach to defining energy poverty is based on access to energy instead of actual consumption of energy. Access may depend on the specific type of fuel and requires both physical access and financial access. Pachauri mentions a few research articles which have shown how access to more efficient energy sources is related to improvements in well being. He summarizes the findings of this research in the following statement. “Thus, what distinguishes a poor household from a better off one is also the wider range of choice in terms of which fuels to use (more efficient, more convenient, less polluting), and which equipment and appliances to buy” (Pachauri et al. 2004).

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